DECam calibration workshop, TAMU
April 20th, 2009

DECam Spectrophotometric Calibration

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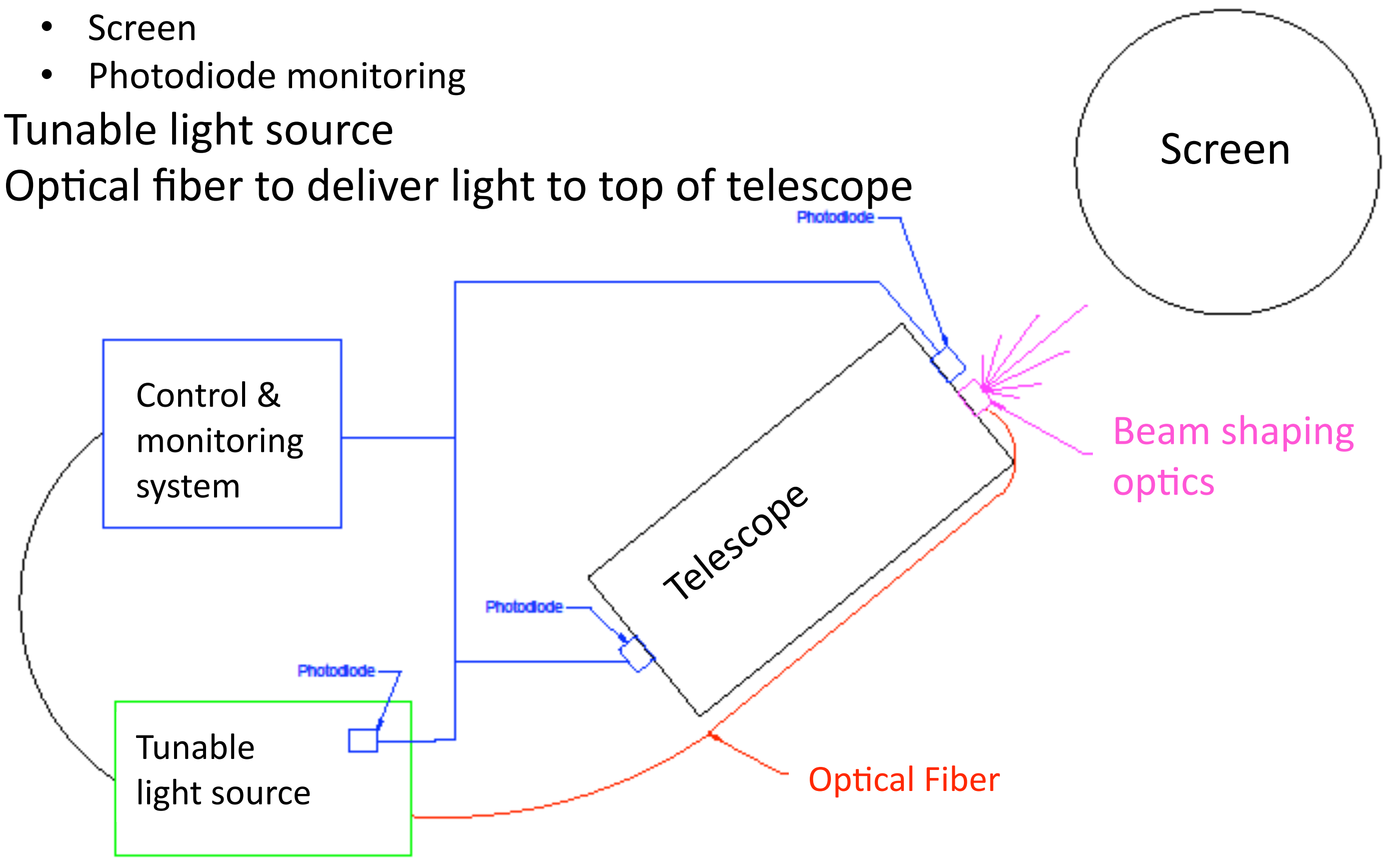
Spectrophotometric Response Calibration

- Requirements
  - Tunable across g, r, i, z and Y (385-1100nm)
    - Goal 330 nm (u)
  - Stable and rugged, need to work reliably with limited maintenance
  - Narrow bandwidth (2-3 nm or less) to be able to probe filter edges.
  - Spectral Power greater than 1 mW/nm to keep integrating times reasonable (Scan all 5 DES filters in less than 4 hours)

Schematic of the Spectrometric Calibration setup

Description

- Use tunable light source from 330nm to 1100nm to probe the system response at every wavelength
- Scan with each filter to get the response function vs wavelength in each band
- Uses same basic components as the daily flatfield
  - Screen
  - Photodiode monitoring
- Tunable light source
- Optical fiber to deliver light to top of telescope



Potential Tunable Light Sources

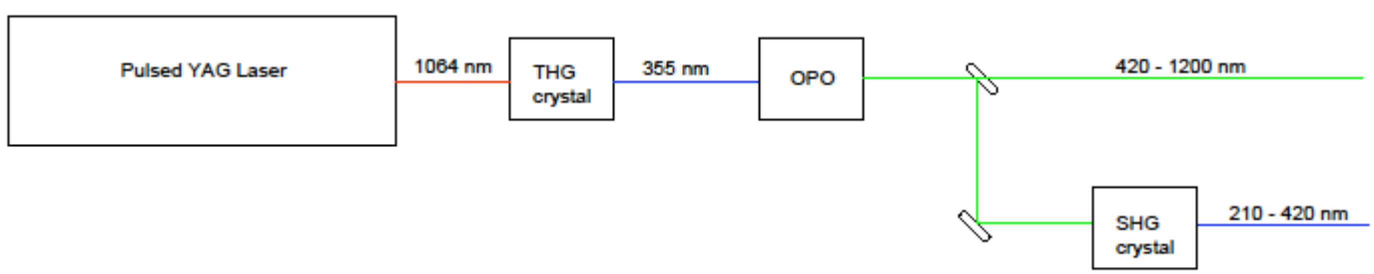
- Tunable lasers
- Monochromator
- Acousto-optic tunable filters
  - Crystal damage below 400nm
  - Limited power
- Supercontinuum generating fiber
  - Requires Ultra-short pulse laser ($$$)
  - No power below 400nm, still experimental

Light source: tunable laser

- Variety of tunable laser
  - Ti:Sapphire (700– 1100nm)
  - Dye laser
    - wavelength range depends on actual dye
  - Laser diodes (mostly in NIR, max 100nm tuning range)
- Only solution: OPOs
  - The only way to span from 330nm to 1100nm
  - The OPO (optical parametric oscillator) absorbs one photon and converts it to two photons of lower energy
    - We can tune the output wavelength by changing the temperature or angle of the OPO crystal.

OPO Tunable laser

- Based on a Nd:YAG laser
- Many steps required to get u, g, r, I, z and Y,
  - 1064nm YAG fundamental
  - 355nm obtained through THG
  - 420nm – 1200nm obtained with OPO
  - 210-420nm obtained with SHG
- This increases the alignment problems
- Commercial systems claim to be easy to use



Tunable laser

- Pros
  - Very Narrow linewidth (~5cm^{-1} or ~0.1nm @500 nm)
  - Good power output over whole wavelength range > 10mW
  - Can be fiber coupled easily
  - Computer controlled wavelength selection (with some human intervention)
- Cons
  - Expensive ~100k$,
  - May require frequent re-alignment,
  - Water cooled.
  - Pump lamp replacement and general maintenance.
    - Pump lifetime (30 milion pulses or 800 hours @ 10 Hz)
  - Beam Power Stability of a few %, intrinsic to non-linear processes
    - Can be compensated by closed loop monitoring

Light source: Monochromator

- Monochromator based source
  - Broadband light source
    - Xe or Halogen
    - Requires compact and bright arc or filament for efficient coupling in mono slit.
      - Acceptance angle of the monochromator limits how much we can focus the beam.
    - Limited by filament or arc brightness
  - Monochromator
    - Can have 3 gratings to cover whole range efficiently
    - Compromise: output power depends on (slit width)^2, narrow band= less power
  - Slit output is coupled to a fiber
    - Fiber bundle

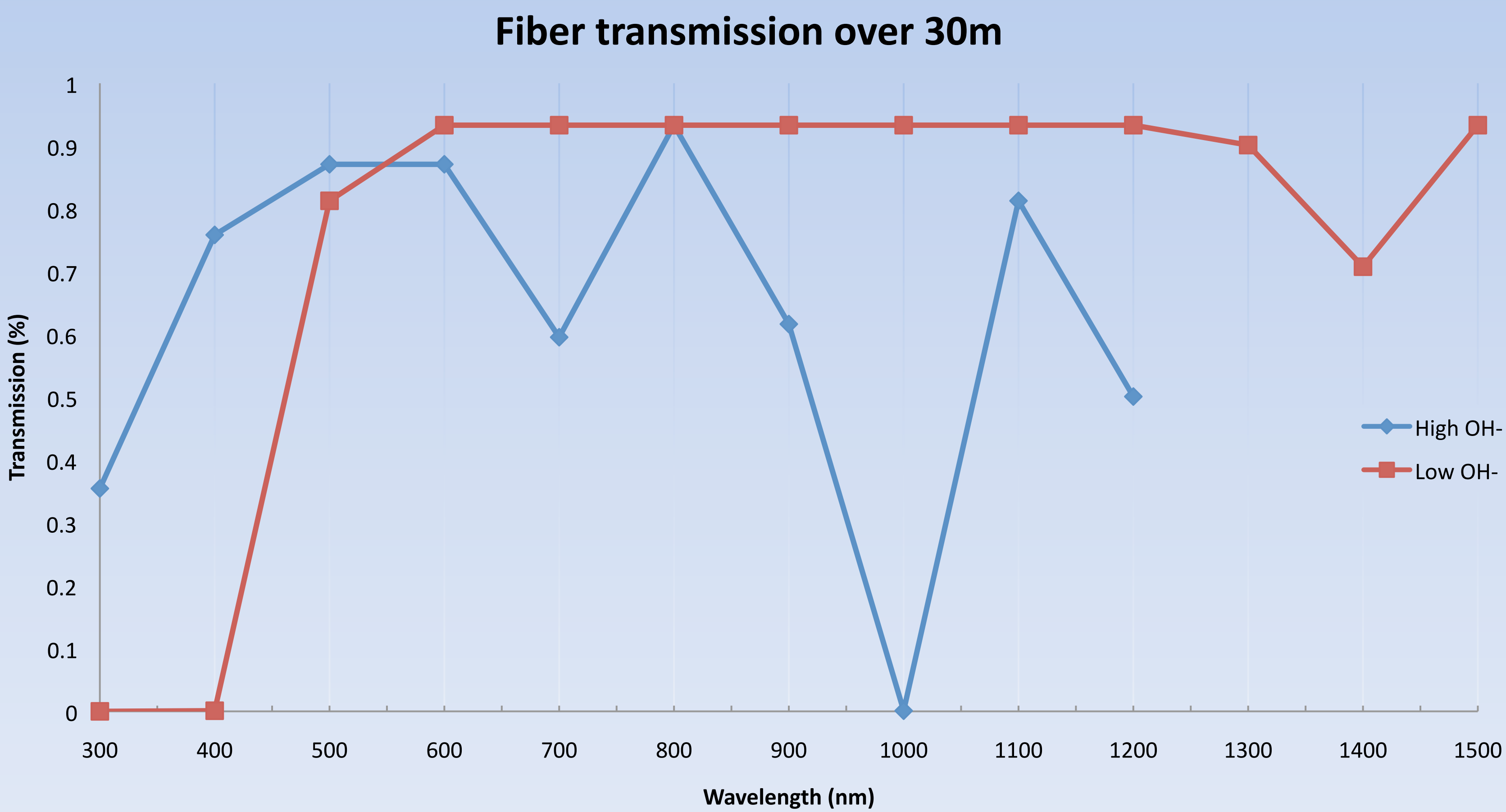
Monochromator

- Pros
  - More rugged and simpler than laser.
  - Computer controlled tuning (Motorized slit, grating turret, lamp changer)
  - Cheaper than laser ~ 25 k$
- Cons
  - Lower power/nm, especially at UV wavelength
  - Large bandwidth (2-3 nm) required to get enough signal (power ~ bandwidth^2)
  - Fiber coupling more complicated (slit to fiber)

Optical Fibers

- Fibers are the only option, light source 30m from end of telescope
- Fiber ends fixed top of telescope
- Beam shaping Optics will insure the fiber output is uniform on the screen
- Use of bifurcated fibers
  - to separate beam and get multiple illumination points
  - in-line monitoring
- Special UV fiber (Low OH-) is required below 500nm

UV and Vis-IR fibers



Monitoring and calibration

- Similar to the system described in daily flat
  - Photodiodes
    - In line
    - Facing the screen
    - In the focal plane
  - In line photodiode used for retroactive loop
    - Eliminates fluctuations and long term drift
    - Essential because source output depends on several factors
      - Laser pump lamp degradation
      - Laser Alignment
      - Monochromator slit size
      - Fiber coupler efficiency
      - Etc…
  - Calibration of photodiodes based on NIST standards
    - Will transfer the calibration using our own calibration system

Available Absolute NIST calibrated references

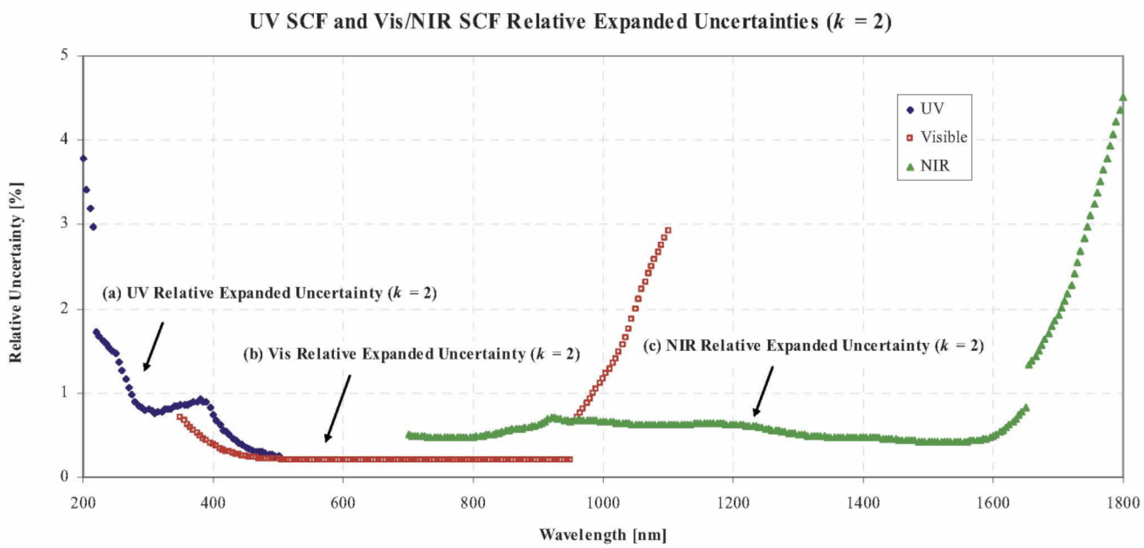


Figure 2.1. The relative expanded uncertainties ($k = 2$) for NIST spectral power responsivity measurements in the (a) UV, (b) visible, and (c) NIR. Three different detector types are used as working standards for the UV, visible, and NIR regions.

Source: **NIST Special Publication 250-41 (2008)**

UV: UV enhanced Si
Vis: Si Photodiode
NIR: InGaAs photodiode

Proof of concept

- Currently working on a monochromator based spectrometric calibration setup for LCO
- Use it to calibrate the Swopes and Dupont
- Good proof of concept for transfer to a bigger telescope

Summary

- Will use same screen and monitoring photodiodes as for Daily flat
- Price and durability are drawbacks of tunable laser
- Available power is the problem with the Monochomator
- Fibers have reasonable losses should be good
- We will test a mono system for LCO later this year.